

## CLAIMS

- 1) A new type of focal plane array — multicycle integration focal plane array (MIFPA), linear or area, which, unlike the existing FPA of single-cycle integration, utilizes three additional MOS switches (M1, M2, and M3 of fig. 1) and one additional capacitance (C1 of fig. 1) for each pixel to perform on-chip multicycle integration.
- 2) Applications of MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.
- 3) Three operational modes of MIFPA — lock-in (LI-), gated (G-), and gated lock-in (GLI-) modes.
- 4) A new type of focal plane array — lock-in multicycle integration focal plane array (LI-MIFPA), linear or area, which possesses the following features:
  - a) it uses an active or passive modulator to modulate the signal;
  - b) it does not modulate dark and/or background current;
  - c) it uses a correlated multicycle integrator for each pixel, so that the signal current is accumulated while the background and/or dark current is cancelled;
  - d) the integration time of the LI-MIFPA can be many orders longer than that of the existing FPA technology;
  - e) therefore, the signal to noise ratio, dynamic range, and low frequency or  $1/f$  noise of the LI-MIFPA can be improved by many orders in comparison with the existing FPA technology.

5) Applications of LI-MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.

6) A new type of focal plane array — gated multicycle integration focal plane array (G-MIFPA), linear or area, which has the same multicycle correlated integrator for each pixel as the LI-MIFPA, is programmed to operate in the gated mode, and possesses the following features:

a) it uses a pulsed light source to generate a repetitive signal (as in the case of IR fluorescence spectroscopy using nano-second pulse laser excitation);

b) the G-MIFPA is used when the number of integrated signal electrons is many orders smaller than that of the background and/or dark current electrons  $\alpha I_s \ll I_b$ , but  $\alpha I_s$  is not  $\ll I_b$ ;

c) in G-MIFPA the direction of integration of the correlated multicycle integrator does not change as in the LI-MIFPA; The integrator is turned on by a trigger signal from the gate control circuit to integrate the signal photocurrent pulse, and turned off after a certain increment of time;

d) the integration time of the G-MIFPA can be many orders longer than that of the existing FPA technology;

e) therefore, the signal to noise ratio, dynamic range, and low frequency or  $1/f$  noise of the G-MIFPA can be improved by many orders in comparison with the existing FPA technology.

7) Applications of G-MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.

8) A new type of focal plane array — gated lock-in multicycle integration focal plane array (GLI-MIFPA), linear or area, which has the same multicycle correlated integrator for each pixel as the LI-MIFPA, is programmed to operate in the gated lock-in mode, and possesses the following features:

- a) it uses a pulsed light source to generate a repetitive signal (as in the case of LWIR spectroscopy using nano-second pulse laser excitation);
  - b) the GLI-MIFPA is used when the signal is not only short, but is also associated with a much stronger background (  $\alpha \ll 1, I_s \ll I_b$  );
  - c) in GLI-MIFPA, the correlated multicycle integrator goes through three phases (Fig. 5.b). In  $\phi_1$ , which lasts  $\alpha\tau$ , the integrator integrates both the signal pulse and strong background currents. In  $\phi_2$ , which has the same duration as  $\phi_1$ , the integrator reverses its direction of integration, and cancels the background of  $\phi_1$ . In  $\phi_3$ , which lasts much longer than  $\phi_1$  or  $\phi_2$ , the integrator is turned off.
  - d) the GLI-MIFPA combines the advantage of the G-mode — reduction of the on-time of the integrator to increase the integration time — and that of the LI mode — cancellation of background to increase the integration time;
  - e) therefore, the signal to noise ratio, dynamic range, and low frequency or  $1/f$  noise of the G-MIFPA can be improved by many orders in comparison with the existing FPA technology.
- 9) Applications of GLI-MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.
  - 10) A new device — correlated multicycle integrator (comprising of one operational amplifier or source follower and four MOS switches), which can be programmed to control the MIFPA to operate in lock-in (LI-), gated (G-), or gated lock-in (GLI) mode.

